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Sorta, kemijska zaštita i djelovanje biostimulata na ozimu pšenicu

**Iljkić, D., Vuković, M., Dvojković, K., Horvat, D., Szpunar-Krok, E., Jańczak-Pieniążek, M., Rastija, M.**

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# VARIETY, ANTIFUNGAL CHEMICAL PROTECTION, AND BIOSTIMULATOR EFFECT ON THE WINTER WHEAT STATUS

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Preliminary communication
*Prethodno priopćenje*

**SUMMARY**

***Wheat production faces several challenges, including climate change, expensive inputs, rising market demand, and environmental pollution, which necessitates alternative solutions. This study aimed to analyze the impact of applying the antifungal chemical protection and biostimulators on the winter wheat. The field experiment was set up during the 2022–23 growing season according to the RCBD in four replicates on the surface area of the Agricultural Institute Osijek. In total, three treatments (control, antifungal chemical protection, and antifungal chemical protection + biostimulator) and six varieties of wheat origin from Croatia (Žitarka, Golubica, and Felix) and Poland (Venecja, Plejada, and Opoka) were applied, and a total of sixteen properties were analyzed. The temperatures and precipitation data during the vegetation season were monitored. According to the analysis of variance, variety was significant for fourteen traits, treatment for six traits, and their interaction for all sixteen traits. Generally, average wheat yield was low (4.60 t ha***$^{-1}$***) but the quality, in context of protein content, was quite high (14.8%). The biostimulator had a positive effect on the yield, kernel number per ear, hectoliter mass and wet gluten/protein ratio. Varieties originating from Poland showed slightly higher values of agro-morphological properties while Croatian varieties showed slightly higher values of grain quality.***

***Keywords: wheat variety, antifungal chemical protection, biostimulator, properties, quality***

## INTRODUCTION

Globally, cereals are the most common agricultural crops, and wheat reigns supreme, occupying the top third position, according to the Food and Agriculture Organization of the United Nations' (FAO's) FAOStat database (2023). It is indispensable in everyday life a vital source of carbohydrates, proteins, and minerals (Shewry and Hey, 2015; Igrejas and Branlard, 2020), a raw material for many industries (Shevkani et al., 2016; Jackowski et al., 2020), a trading commodity (Erenstein et al. 2022), a building material (Barbieri et al., 2020; Zou et al., 2021), and the like. Wheat has a special meaning in the underdeveloped and less developed countries because it provides an important source of energy. In the middle of the last century, the development of wheat in the context of productivity and agricultural technology has been constantly increasing. The Green Revolution significantly boosted wheat production by introducing the semi-dwarf, high-yielding varieties. However, these varieties often required an increased use of fertilizers and pesticides (Ameen and Raza, 2017).

Nowadays, wheat cultivation success is a combination of environmental factors, applied agricultural techniques, and genetics—that is, a variety. Adverse weather conditions and constant negative fluctuations impair both the yield stability and wheat quality. Furthermore, pests, plant pathogens, and weeds are responsible for most of the losses associated with agricultural crops either in the field or in storage (Baričević et al., 2023). Wheat is particularly sensitive to plant diseases, and today's intensive cultivation is almost impossible without the application of chemical protection. General, mineral fertilizers and fungicide applications are the major items in wheat production, so an efficient chemical protection plays an important role. However, increasing input in wheat

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production and raising awareness of the impact of agriculture on environmental pollution is focused (Işik and Özbuğday, 2021), so the new alternatives are constantly sought for. Combining the application of biostimulators and chemical protection can be one of the methods for sustainable agriculture. The use of biostimulators can be a promising and environment-friendly innovation to field production (Ayed aet al., 2022). Also, the right selection of wheat genotypes, reducing the use of fungicides and the use of appropriate plant nutrition substances, would contribute to the solution of these issues.

The occurrence of plant diseases mostly depends on the climate change and climatic conditions (Španić et al., 2023), and moderate temperatures and high humidity are the most important factors (Prasad et al., 2021). In Croatia, the most important wheat diseases that occur almost every year are *Septoria tritici* blotch (STB), stripe rust (SR) or yellow rust (YR), powdery mildew (PM), and *Fusarium* head blight, or the FHB, (Radan et al., 2014; Spanic et al., 2021). Depending on a plant disease, the STB reduce yields up to 50% (Bellameche et al., 2020), SR or YR from 10 to 70% (Carmona et al., 2020), PM from 35 to 62% (Mehta, 2014; Kang et al., 2020) and the FHB up to 80% of yield losses (Matelioniene et al., 2022; Alisaac and Mahlein, 2023). In addition to a yield reduction, common to all diseases is a negative effect on quality and the appearance of mycotoxins.

This study's objective was to examine the impact of chemical protection against fungal diseases and the biostimulators on six varieties of winter wheat originating from Poland and Croatia during the 2022-23 growing season in field conditions.

## MATERIALS AND METHODS

### Field trials

The two-factorial field experiment was set up during the 2022-23 growing season at the Agricultural Institute Osijek, eastern Croatia (45° 52′ 9970″ N and 18° 75′ 5489″ E). Soybean was a precrop, followed by basic and additional soil tillage and pre-sowing preparations. Based on a soil analyses, 100 kg ha$^{-1}$ of urea (46 % N) and 200 kg ha$^{-1}$ of NPK 0:20:30 were applied. Additionally, two top dressings were performed during the growing season. The first top dressing was performed on 13 February 2022, in the tillering phase with 150 kg ha$^{-1}$ of CAN (calcium ammonium nitrate, 27 % N), and the second was performed on 22 March 2022 in the steam-elongation phase with 100 kg ha$^{-1}$ of CAN. The winter wheat was sown on 19 October 2022 in four repetitions, and the basic plot was 7.56 m$^2$. A total of six varieties of winter wheat, created at the Agricultural Institute Osijek (Žitarka, Golubica, and Felix) and at the seed company Hodowla Roslin Strzelce (Venecja, Plejada, and Opoka) were sown. The field experiment consisted of a total of three treatments. The first there of was a without-fungicide treatment (WFT). The second one included three fungicide protections (FP) with commercial fungicides at the plant growth stages BBCH 33, BBCH 47, and BBCH 61. The third treatment included a combination of the FP and the application of a biostimulator Fertileader Vital (9% N, 5% P, 4% K, 0.05% B, 0.02 % Cu, 0.02 % Fe, 0.1% Mn, 0.01% Mo, 0.05% Zn, IPA, GB and AA) during the BBCH 47 and the BBCH 61 phase. Crop protection against weeds and pests was performed equally for all treatments.

### Weather conditions

During the 2022-23 season, total precipitation and air temperature were quite similar to the long-term mean (Table 1). There were slightly more precipitations (4%), and the air temperatures were higher by 9%. However, during the growing season, wheat was exposed to a more stressful environment than usual due to a very wet and extremely warm winter period (November-February), which did not favor a successful wheat production. Moreover, during the steam-elongation growth phase, a mean air temperature was below the optimal value for winter wheat.

**Table 1. Weather conditions during the 2022-23 winter-wheat growing season and the 2002-20 long-term mean (LTM) of the Climatological Station Klisa-Osijek (Croatian Meteorological and Hydrological Service, 2023)**

*Tablica 1. Vremenske prilike tijekom vegetacije ozime pšenice 2022./2023. i višegodišnji prosjek (VGP) klimatološke postaje Klisa - Osijek (Državni hidrometeorološki zavod, 2023.) od 2002. do 2020.*

| Year / Month<br>*Godina / Mjesec* | X | XI | XII | I | II | III | IV | V | VI | VII | Total / *Ukupno* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rainfall (mm) / *Oborine (mm)* | | | | | | | | | | |
| 2022/2023 | 12 | 78 | 60 | 65 | 54 | 28 | 76 | 99 | 52 | 56 | 580 |
| LTM / *VGP* | 61 | 48 | 45 | 43 | 47 | 42 | 47 | 87 | 78 | 60 | 558 |
| Deviation (%) / Odstupanje (%) | -80 | +62 | +33 | +51 | +15 | -33 | +62 | +14 | -33 | -7 | +4 |
| | Air temperature (°C) / *Temperature (°C)* | | | | | | | | | | Average / *Prosjek* |
| 2022/2023 | 13.6 | 7.9 | 4.7 | 4.7 | 3.8 | 8.8 | 10.9 | 17.3 | 21.3 | 24.2 | 11.7 |
| LTM / *VGP* | 12.0 | 7.2 | 2.2 | 0.6 | 2.4 | 7.2 | 13.0 | 17.6 | 21.6 | 23.4 | 10.7 |
| Deviation (%) / *Odstupanje (%)* | +13 | +10 | +114 | +683 | +58 | +22 | -16 | -2 | -2 | +3 | +9 |

**Plant material sampling and analysis**

A few days prior to the harvest, plant material samples were taken manually. To determine the agronomic and morphological properties (i.e., a kernel number per ear, plant height, stem weight, ears length, and weight), 30 plants from each repetition were taken by random selection. Afterwards, in the stage of full ripening, the grain was harvested from the whole plot using an automatic special machine Wintersteiger. Grain moisture (%) and hectoliter weight ($kghL^{-1}$) were measured by the GAC 2100 (Dickey-John) analyzer, while the Marvin grain analyzer calculated the 1,000 kernel weight (g). The yield was calculated on the basis of 14% grain moisture, and the quality properties (protein and hardness) were measured by the Infratec *1241*, based on the near infrared reflectance in the Agrochemical laboratory at the Agricultural institute Osijek. The Zeleny sedimentation value, wet gluten and gluten index, and the Hagberg-Perten falling number were analyzed according to the standard methods (ICC method No 116/1, ICC method No 155, and ICC 107/1, respectively), while the wet gluten/protein ratio was calculated.

**Statistics**

The MS Excel and the SAS Software 9.1.4 (SAS Institute Inc.) computer programs were used for statistical data processing. The analysis of variance and the F test for each treatment and replication were conducted and administered. The statistical significance of the differences between the average tested values of the factors and treatments was assessed using the LSD value.

## RESULTS AND DISCUSSION

As the main trait, the yield in the conducted research was low, in comparison with the average values at the Croatian level (4.6 t $ha^{-1}$ and 5.6 t $ha^{-1}$, respectively), according to the Croatian Bureau of Statistics (DZS, 2024). However, the average yield was associated with a very low yield in the control treatment without chemical protection against plant disease, which is not a usual measure in wheat production. The analysis of variance manifested a significance for variety, treatments, and their interactions (Table 2). Out of a total of sixteen investigated traits, variety (A) was significant for fourteen, treatment (B) for only six, and interaction (A x B) for all sixteen traits. Although the treatment (B) did not manifest significance for many traits, it should be emphasized that it was significant for the most important traits in production, yield, yield component (kernel number per ear), hectoliter weight, and some quality parameters.

In the context of wheat production, the traits depicted in Figure 1 are most important. Although the average yield was relatively low, it should be noted that there was a very large significant variation between the varieties and the applied treatments. The Venecja (6.35 t $ha^{-1}$) and Plejada (5.34 t $ha^{-1}$) varieties achieved the highest average yield had, and the lowest was achieved by the variety Golubica variety (3.48 t $ha^{-1}$). The first two high-yielding varieties had the high yields in the control treatment when compared to the others, which indicates a good tolerance to plant diseases. In terms of the applied treatments, statistically the highest yield was achieved by the FP+BS (5.58 t $ha^{-1}$) followed by the FP (4.93 t $ha^{-1}$), while the control treatment without the application of chemical protection achieved only 3.29 t $ha^{-1}$. Although the analysis of variance did not manifest significance between the FP and the FP+BS, the higher yield in the treatment with the biostimulator (0.65 t $ha^{-1}$) justifies its use. A positive combination of chemical protection and biostimulator was confirmed by Iwaniuk et al. (2022). In a four-year experiment, the highest wheat yield was achieved in a combination of sulfonylurea enriched by a humic biostimulator (up to 6.80 t $ha^{-1}$). Similarly, Pačuta et al. (2021) prove that the highest grain yield was on the fertilized variant with humic substances, while Lozowicka et al. (2022) emphasize the importance of the combination of different active substances of herbicides and fungicides in a combination with biostimulators as the best solution for the achievement of a high yield and of the best profit. In our research, Venecja and Plejada had the highest kernel number per ear (32 and 30, respectively), as well as the FP+BS treatment if compared with the FP and WFP treatments (31, 28 and 24 kernel number per ear). Furthermore, 1,000 grain mass and the hectoliter mass distribution of wheat variety was different. Žitarka (26.8 g), Opoka (26.5 g), and Plejada (26.1 g) achieved the highest value of 1,000 grain mass in average, while Plejada (75.1 kg $hl^{-1}$), Felix (74.9 kg $hl^{-1}$), and Žitarka (74.3 kg $hl^{-1}$) averagely had the highest value of hectoliter mass (Figure 1). Fungal protection, and especially the use of a biostimulator, was significant and much higher if compared with the control treatment for the hectoliter mass (73.9 kg $ha^{-1}$, 74.6 kg $ha^{-1}$ and 70.9 kg $ha^{-1}$), while the weight of 1,000 grains was not affected by any treatment. Our study indicated that FP+BS were the most effective strategies for increasing the yield, kernel number per ear, and the hectoliter mass, whereas Kristek et al. (2023) state that biopreparations had a positive effect on the yield, protein content, 1,000 grain mass, and hectoliter mass.

**Table 2. The average values and statistical analysis of the tested properties for all factors**
*Tablica 2. Prosječne vrijednosti i statistička analiza ispitivanih svojstava za sve* **čimbenike**

| Properties / *Svojstvo* | Average / *Prosjek* | $LSD_{0.05}$ value and significance / *$LSD_{0.05}$ vrijednost i značajnost* | | |
|---|---|---|---|---|
| | | Genotype (A) / *Sorta (A)* | Treatment (B) / *Tretman (B)* | Interaction A x B / Interakcija *A x B* |
| | Agronomic traits / *Agronomska svojstva* | | | |
| Y / *P* | 4.60 | 1.042 * | 0.724 * | 0.410 * |
| KNE / *BZK* | 27.9 | 4.01 * | 2.87 * | 5.26 * |
| TKW / *MTZ* | 24.8 | 3.85 * | ns | 6.46 * |
| HW / *HM* | 73.2 | 2.64 * | 2.06 * | 1.60 * |
| GM /*VZ* | 12.2 | 0.63 * | ns | 0.97 * |
| | Morphological traits / *Morfološka svojstva* | | | |
| PH / *VB* | 78.7 | 3.51 * | ns | 5.11 * |
| SM / *MV* | 63.4 | 10.58 * | ns | 16.96 * |
| EL / *DK* | 9.10 | 0.68 * | ns | 0.90 * |
| EM / *MK* | 39.7 | ns | 4.45 * | 9.91 * |
| | Quality traits / *Svojstva kvalitete* | | | |
| P / *P* | 14.8 | 0.32 * | ns | 0.27 * |
| SED / SED | 44.3 | 2.21 * | ns | 2.14 * |
| WG / *VG* | 33.6 | 0.82 * | ns | 0.90 * |
| GI / *GI* | 88.4 | 2.53 * | ns | 4.64 * |
| FN / *BP* | 346 | ns | 10.21 * | 19.80 * |
| WG/ P / *VG/P* | 2.28 | 0.07 * | 0.06 * | 0.07 * |
| H / *T* | 66.8 | 6.65 * | ns | 7.88 * |

Y – yield (t $ha^{-1}$); KNE – kernel number per ear; TKW – thousand kernel weight (g); HW – hectoliter weight (kg $hL^{-1}$); GM – grain moisture (%); PH – plant height (cm); SM – straw mass (g); EL – ear length (cm); EM – ear mass (g); P – total grain protein (%); SED – sedimentation value (ml); WG – wet gluten (%); GI – gluten index; FN (s) – Hagberg-Perten falling number; WG/P – wet gluten protein ratio; H – hardness; ns – non significant /

*P – prinos (t $ha^{-1}$); BZK – broj zrna po klasu; MTZ – masa 1000 zrna (g); HM – hektolitarska masa (kg $hl^{-1}$); VZ – vlaga zrna (%); VB – visina biljke (cm); MV – masa vlati (g); DK – dužina klasa (cm); MK – masa klasa (g); P – ukupne bjelančevine zrna (%); SED – sedimentacijska vrijednost brašna (ml); VG – vlažni gluten (%); GI – glutenski indeks; BP – broj padanja prema Hagberg-Parten-u; VG/P – omjer vlažnoga glutena bjelančevina; H – tvrdoća; ns – nije značajno*

Additionally, agronomic and morphological traits of a variety, treatment, and their interactions were analyzed. Grain moisture ranged from 11.0% (Golubica) to 13.2% (Plejada) and, in general, the wheat varieties from Poland had a higher grain moisture value. Also, the plant height and straw mass were much higher in the varieties from Poland. On average, plant height was 85.4 and 71.9 cm while straw mass was 77.0 g and 49.9 g in favour of varieties from Poland. Although the Polish varieties were more robust in terms of height and weight, this did not have a strong effect on the ear length. On average, the difference in ear length amounted to only 0.8 cm (9.5 cm and 8.7 cm, respectively) in favor of Polish varieties. Ear mass was not significant for any varieties. The listed advantages of varieties from Poland can be a result of longer vegetation period and a colder environment in which the varieties were created.

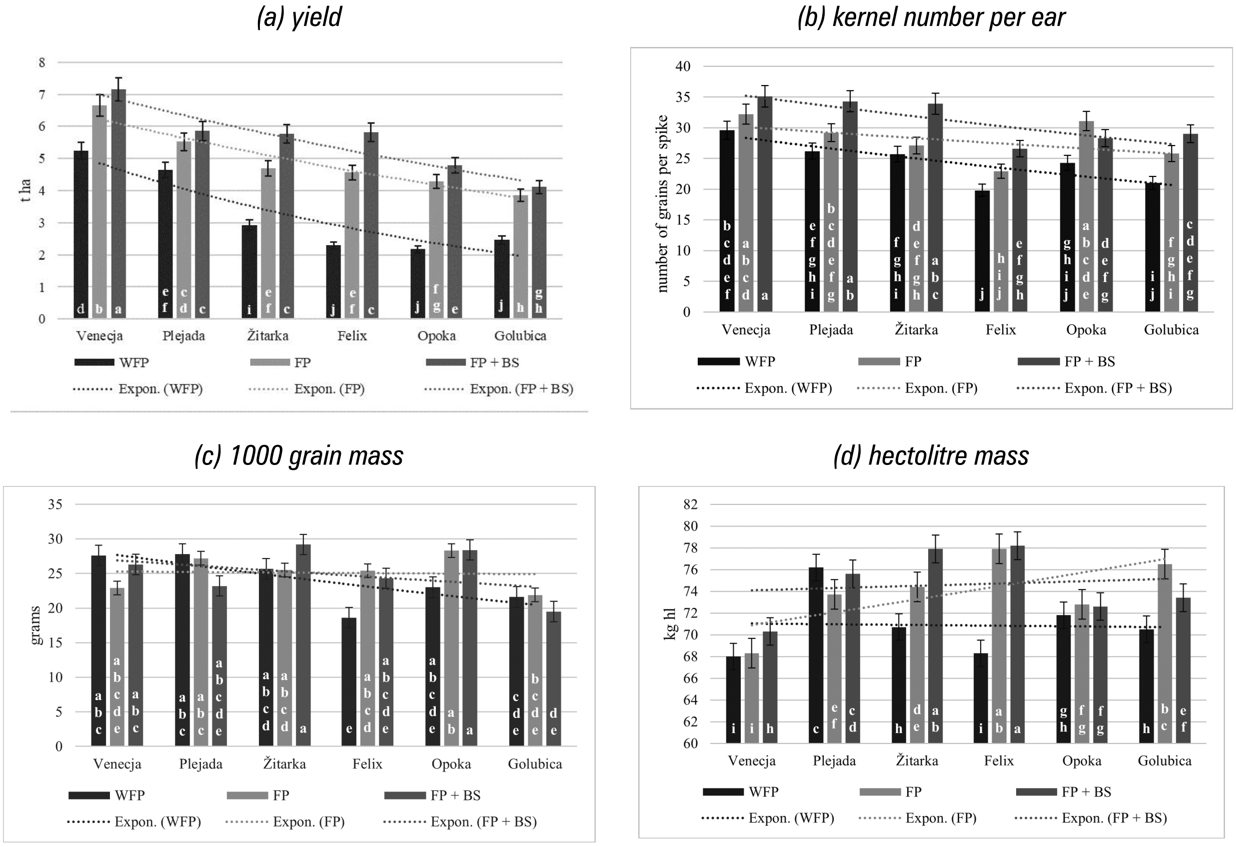


**Figure 1. The yield (a), yield components (b and c), and hectoliter mass (d) of six wheat varieties among treatments during the 2022–23 vegetation season. Different letters represent significance at $p < 0.05$. WFP – without fungal protection; FP – fungal protection; FP+BS – fungal protection + biostimulator.**

*Grafikon 1. Prinos (a), komponente prinosa (b i c) i hektolitarska masa (d) šest sorata pšenice između tretmana tijekom vegetacijske sezone 2022./2023. Različita slova predstavljaju signifikantnost pri $p < 0.05$. WFP – bez zaštite fungicidima; FP – zaštita fungicidima; FP+BS – zaštita fungicidima + biostimulator.*

The analysis of variance did not establish evidence of any significance for grain moisture and other morphological properties (except the ear mass), but, in general, the higher values were observed in the treatments of fungicidal protection and biostimulators application. The values varied from 77.0 cm (WFP) to 79.6 cm (FP+BS) for plant height, from 59.9 g (WFP) to 69.3 g (FP+BS) for straw mass, from 8.81 cm (WFP) to 9.44 cm (FP) for the ear length, and from 31.8 g (WFP) to 44.2 g (FP) for the ear mass, respectively. The variations in the interaction between the variety and treatments were even more pronounced.

The quality of wheat grains is increasingly important in the aspect of human nutrition and malnutrition, in the context of the milling industry, the presence of mycotoxins, and the like. In our research, the seven most important quality parameters were analysed (Table 3). Unlike the previously analyzed properties in terms of grain quality, however, it is not possible to draw a clear line between the Polish and Croatian varieties. The protein content was significantly influenced by a variety (A) and an interaction of variety and treatment (A x B), while the application of fungicide protection and biostimulators was not significant, except for the wet gluten/protein ratio. Only two varieties, one from each country, achieved a significant protein content, higher than 15% (i.e., Golubica and Opoka). Statistically, the highest sedimentation value achieved was that of the Golubica, Felix, and Venecja, wet gluten in Golubica, and the wet gluten/protein ratio in Žitarka and Golubica. Furthermore, Venecja and Felix had significantly high values of gluten index, and Golubica had significantly high values for hardness.

**Table 3. Quality indicators of the tested genotypes, treatments, and their interactions**

*Tablica 3. Pokazatelji kvalitete ispitivanih genotipova, tretmana i njihove interakcije*

| Variety/Treatment<br>*Sorta / Tretman* | | P (%) /<br>P (%) | SED (ml) /<br>SED *(ml)* | WG (%) /<br>*VG (%)* | WG/P<br>*/ VG/P* | GI /<br>*GI* | FN /<br>*BP* | H /<br>T |
|---|---|---|---|---|---|---|---|---|
| | | Variety / *Sorta* | | | | | | |
| Venecja (V) | | 14.0 $^{c}$ | 47.0 $^{a}$ | 30.6 $^{d}$ | 2.18 $^{c}$ | 97.8 $^{a}$ | 342 | 60.7 $^{de}$ |
| Plejada (P) | | 14.4 $^{b}$ | 41.3 $^{b}$ | 32.2 $^{c}$ | 2.25 $^{bc}$ | 93.3 $^{b}$ | 343 | 63.5 $^{cd}$ |
| Opoka (O) | | 15.6 $^{a}$ | 41.3 $^{b}$ | 34.5 $^{b}$ | 2.20 $^{c}$ | 81.2 $^{c}$ | 351 | 55.4 $^{e}$ |
| Žitarka (Ž) | | 14.5 $^{b}$ | 41.0 $^{b}$ | 34.6 $^{b}$ | 2.38 $^{a}$ | 79.5 $^{c}$ | 356 | 71.8 $^{b}$ |
| Golubica (G) | | 15.8 $^{a}$ | 47.8 $^{a}$ | 37.4 $^{a}$ | 2.37 $^{a}$ | 81.2 $^{c}$ | 339 | 80.5 $^{a}$ |
| Felix (F) | | 14.3 $^{bc}$ | 47.5 $^{a}$ | 32.5 $^{c}$ | 2.28 $^{b}$ | 97.3 $^{a}$ | 341 | 69.1 $^{bc}$ |
| | | Treatment / *Tretman* | | | | | | |
| WFP | | 14.9 | 44.2 | 33.4 | 2.23 $^{b}$ | 89.2 | 353 $^{a}$ | 62.8 |
| FP | | 14.8 | 45.6 | 33.6 | 2.26 $^{b}$ | 88.4 | 342 $^{b}$ | 67.5 |
| FP + BS | | 14.6 | 43.3 | 33.9 | 2.34 $^{a}$ | 87.6 | 342 $^{b}$ | 70.2 |
| | | Interactions / *Interakcija* | | | | | | |
| | V | 14.3 $^{gh}$ | 45.0 $^{ef}$ | 29.6 $^{k}$ | 2.01 $^{d}$ | 99.0 $^{a}$ | 342 $^{cdef}$ | 60.4 $^{gh}$ |
| | P | 14.2 $^{ghi}$ | 40.5 $^{ghi}$ | 31.5 $^{ij}$ | 2.25 $^{bc}$ | 93.0 $^{b}$ | 352 $^{bcde}$ | 63.2 $^{efg}$ |
| WFP | O | 15.4 $^{cd}$ | 39.5 $^{j}$ | 33.9 $^{ef}$ | 2.20 $^{c}$ | 82.0 $^{c}$ | 364 $^{ab}$ | 55.7 $^{gh}$ |
| | Ž | 14.9 $^{e}$ | 39.0 $^{j}$ | 35.7 $^{bc}$ | 2.40 $^{a}$ | 80.5 $^{cd}$ | 381 $^{a}$ | 69.2 $^{def}$ |
| | G | 16.5 $^{a}$ | 50.0 $^{ab}$ | 38.0 $^{a}$ | 2.30 $^{b}$ | 81.5 $^{cd}$ | 343 $^{cdef}$ | 74.0 $^{cd}$ |
| | F | 14.4 $^{fg}$ | 51.0 $^{a}$ | 31.8 $^{i}$ | 2.20 $^{c}$ | 99.0 $^{a}$ | 340 $^{def}$ | 54.3 $^{h}$ |
| | V | 14.0 $^{i}$ | 48.5 $^{bc}$ | 30.7 $^{j}$ | 2.20 $^{c}$ | 97.5 $^{ab}$ | 354 $^{bcd}$ | 59.3 $^{gh}$ |
| | P | 14.7 $^{ef}$ | 43.0 $^{fg}$ | 32.4 $^{hi}$ | 2.20 $^{c}$ | 93.0 $^{b}$ | 347 $^{bcdef}$ | 56.9 $^{gh}$ |
| FP | O | 15.7 $^{bc}$ | 42.5 $^{gh}$ | 34.7 $^{de}$ | 2.20 $^{c}$ | 81.5 $^{cd}$ | 330 $^{f}$ | 54.6 $^{h}$ |
| | Ž | 14.7 $^{ef}$ | 44.0 $^{efg}$ | 33.9 $^{ef}$ | 2.30 $^{b}$ | 81.0 $^{cd}$ | 345 $^{bcdef}$ | 75.3 $^{cd}$ |
| | G | 15.5 $^{cd}$ | 47.5 $^{cd}$ | 37.8 $^{a}$ | 2.40 $^{a}$ | 81.5 $^{cd}$ | 336 $^{def}$ | 83.4 $^{ab}$ |
| | F | 14.4 $^{fg}$ | 48.0 $^{bcd}$ | 32.2 $^{hi}$ | 2.25 $^{bc}$ | 96.0 $^{ab}$ | 339 $^{def}$ | 76.0 $^{bcd}$ |
| | V | 13.9 $^{i}$ | 47.5 $^{cd}$ | 31.7 $^{i}$ | 2.30 $^{b}$ | 97.0 $^{ab}$ | 332 $^{f}$ | 62.7 $^{fg}$ |
| | P | 14.3 $^{gh}$ | 40.5 $^{hij}$ | 32.8 $^{gh}$ | 2.30 $^{b}$ | 94.0 $^{ab}$ | 334 $^{ef}$ | 70.7 $^{cde}$ |
| FP+BS | O | 15.9 $^{b}$ | 42.0 $^{ghi}$ | 35.0 $^{cd}$ | 2.20 $^{c}$ | 80.0 $^{cd}$ | 361 $^{bc}$ | 56.1 $^{gh}$ |
| | Ž | 14.1 $^{hi}$ | 40.0 $^{ij}$ | 34.3 $^{def}$ | 2.45 $^{a}$ | 77.0 $^{d}$ | 344 $^{cdef}$ | 70.9 $^{cde}$ |
| | G | 15.3 $^{d}$ | 46.0 $^{de}$ | 36.5 $^{b}$ | 2.40 $^{a}$ | 80.5 $^{cd}$ | 337 $^{def}$ | 84.0 $^{a}$ |
| | F | 14.1 $^{hi}$ | 43.5 $^{fg}$ | 33.5 $^{fg}$ | 2.40 $^{a}$ | 97.0 $^{ab}$ | 346 $^{bcdef}$ | 77.2 $^{abc}$ |
| Average | | 14.8 | 44.3 | 33.6 | 2.28 | 88.4 | 346 | 66.8 |

WFP - without fungal protection; FP - fungal protection; FP+BS - fungal protection + biostimulator. P – total grain protein (%); SED – sedimentation value (ml); WG – wet gluten (%); WG/P – wet gluten protein ratio; GI – gluten index; FN – Hagberg-Perten falling number; H – hardness. Different letters represent significance at $p < 0.05$ /

*WFP – bez zaštite fungicidima; FP – zaštita fungicidima; FP+BS – zaštita fungicidima + biostimulatori. P – ukupne bjelančevine zrna (%); SED – sedimentacijska vrijednost brašna (ml); VG – vlažni gluten (%); VG/P – omjer vlažnoga glutena i proteina; GI – glutenski indeks; BP – broj padanja prema Hagbergu; H – tvrdoća. Različita slova predstavljaju signifikantnost pri $p < 0,05$.*

## CONCLUSION

Due to many biotic, abiotic, and economical pressure on wheat production, our goal was to asses the impact of variety, antifungal chemical protection, and biostimulator application on the yield, yield parameters, agromorphological traits, and grain quality. Our study has proven that some traits are significantly influenced by biostimulators and fungicide protection, but some depend on the genetic background of the variety. The FP+BS were the most effective strategies and had a positive effect on the yield, kernel number per ear, and hectoliter mass. Concerning the quality parameters, the FP+BS treatment significantly affected the wet gluten/protein ratio due to the observed trend of protein reduction and an increase in the wet gluten. Future research is necessary to examine the treatments with different combinations and amounts of chemical and biostimulator agens.

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# UČINAK SORTE, ANTIFUGALNE KEMIJSKE ZAŠTITE I DJELOVANJE BIOSTIMULATORA NA SVOJSTVA OZIME PŠENICE

***SAŽETAK***

***Proizvodnja pšenice suočava se s nekoliko izazova, uključujući klimatske promjene, skupe ulazne troškove proizvodnje, rastuću potražnju na tržištu i zagađenje okoliša, što zahtijeva alternativna rješenja. Ovo istraživanje imalo je za cilj analizirati utjecaj primjene antifugalne kemijske zaštite i biostimulatora na ozimu pšenicu. Poljski pokus postavljen je tijekom vegetacijske sezone 2022./2023. prema RCBD-u u četiri ponavljanja na površini Poljoprivrednoga instituta Osijek. Ukupno su primijenjena tri tretmana (kontrola, antifugalna kemijska zaštita i antifugalna kemijska zaštita + biostimulator) i šest sorata pšenice podrijetlom iz Hrvatske (Žitarka, Golubica i Felix) i Poljske (Venecja, Plejada i Opoka), a ukupno je analizirano 16 svojstava. Također, praćeni su podatci o temperaturama i oborinama tijekom vegetacijske sezone. Prema analizi varijance, sorte su bile značajne za 14 svojstava, tretman za 6 svojstava, a interakcija za svih 16 svojstava. Općenito, prosječan prinos pšenice bio je nizak (4,60 t ha$^{-1}$), ali je kvaliteta, u kontekstu sadržaja bjelančevina, bila prilično visoka (14,8%). Biostimulator je pozitivno djelovao na prinos, broj zrna po klasu, hektolitarsku masu i omjer vlažnoga glutena/bjelančevina. Sorte podrijetlom iz Poljske pokazale su nešto veće vrijednosti agromorfoloških svojstava, dok su sorte iz Hrvatske pokazale nešto veće vrijednosti kvalitete zrna.***

***Ključne riječi: sorta pšenice, antifugalna kemijska zaštita, biostimulator, svojstva, kvaliteta***

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